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ORIGINAL ARTICLE

Normative Values for a Functional Capacity Evaluation

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ABSTRACT. Soer R, van der Schans CP, Geertzen JH, Groothoff JW, Brouwer S, Dijkstra PU, Reneman MF. Normative values for a functional capacity evaluation. Arch Phys Med Rehabil 2009;90:1785-94.

Objective: To establish normative values for a functional capacity evaluation (FCE) of healthy working subjects.

Design: Descriptive.

Setting: Rehabilitation center.

Participants: Healthy working subjects (N=701; 448 men, 253 women) between 20 and 60 years of age, working in more than 180 occupations.

Interventions: Subjects performed a 2-hour FCE consisting of 12 work-related tests. Subjects were classified into categories based on physical demands according to the *Dictionary of Occupational Titles*.

Main Outcome Measures: Means, ranges, SDs, and percentiles were provided for normative values of FCE, and a regression analysis for outcome of the 12 tests was performed.

Results: Normative FCE values were established for 4 physical demand categories.

Conclusions: The normative values enable comparison of patients' performances to these values. If a patient's performance exceeds the lowest scores in his/her corresponding demand category, then the patient's capacity is very likely to be sufficient to meet the workload. Further, clinicians can make more precise return-to-work recommendations and set goals for rehabilitation programs. A comparison of the normative values can be useful to the fields of rehabilitation, occupational, and insurance medicine. Further research is needed to test the validity of the normative values with respect to workplace assessments and return-to-work recommendations.

Key Word: Rehabilitation.

IN REHABILITATION, OCCUPATIONAL, and insurance medicine, the model of workload (mental and physical task load) and work capacity (ability to execute a task)[1] is frequently used in patients who have chronic, nonspecific musculoskeletal pain. Following this model, imbalance between workload and work capacity (an imbalance in which workload exceeds work capacity) contributes to the onset and persistence of musculoskeletal pain.[2] A balance in which work capacity is at least equal to or exceeds the workload is deemed necessary to return to work successfully. Increase in functioning by restoring the balance between workload and work capacity by means of decreasing load, increasing capacity, or both is a main treatment goal in occupational rehabilitation programs. While this model appears to be practical and logical, supporting evidence (to support this model) remains scarce. One of the reasons may be that objectifying work capacity as well as objectifying workload in relation to functioning at work still is practically and scientifically challenging.[3,4]

To assess workload, questionnaires and direct measurements are used. Questionnaires can be administered practically and at low costs, making their application attractive. A limitation of questionnaires is that subjects are known to report higher workload than can be quantified by direct measurements.[5-7] This may severely threaten the validity of the questionnaire. To gain more objective data on workload, workplace assessments can be used. Workplace assessments, however, when performed correctly, are expensive and time-consuming. Workplace assessment, therefore, is often an inappropriate assessment to measure the workload of an individual patient. Each assessment method has strengths and weaknesses, and a criterion standard for measurement of workload is unavailable.

Direct measurements on work capacity, as proposed by the model of van Dijk et al,[1] can be performed using FCEs. FCEs are evaluations designed to measure the capacity to perform activities and are used to make recommendations for participation in work while considering the person's body functions and structures, environmental factors, personal factors, and health status.[8] FCEs are applied in rehabilitation, occupational, and insurance[9] medicine. In the past few years, there is growing evidence of the added value and psychometric properties of FCEs.[10] FCE may therefore be a useful addition to the assessments listed above.

Worldwide, there are many FCE protocols, all addressing different aspects of work capacity or FC. An FCE protocol can be job specific,[11] pathology specific,[12-14] or of a more generic nature addressing multiple activities of functioning in daily life. To enable the translation of FCE results into a recommendation for work ability, the results can be compared with the physical work demands that are described in the DOT.[15] The DOT is a systematic coding scheme and lists 20 physical work demands of approximately 20,000 different occupations.[15] The

List of Abbreviations

DOT	*Dictionary of Occupational Titles*
FC	functional capacity
FCE	functional capacity evaluation
ICC	intraclass correlation coefficient
ICF	*International Classification of Functioning, Disability and Health*
LBP	low back pain
MET	metabolic equivalent

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DOT classifies all occupations into 5 categories of physical workload, based on the intensity and duration of lifting or carrying and on the amount of METs expenditure needed for the job. These categories are sedentary, light, medium, heavy, and very heavy.[15] However, validity of the DOT has never been scientifically tested nor has it been based on quantitative work-related task analyses, but rather on consensus meetings of experts.[3] Recently, it was explored whether different outcome measures of the WorkWell protocol for FCE could be matched with the work demands of the DOT, and whether this match between work capacity and workload could predict sick leave of patients with chronic LBP in the year after rehabilitation treatment. It was concluded that the results of 7 tests could directly be matched with the work demands of the DOT. However, sick leave and work ability after 1-year follow-up were found not to be predictive.[4,16]

When trying to translate data gathered from an FCE into work recommendations, one has to know whether a specific capacity such as lifting is acceptable and sufficient to meet the workload. In addition, one needs to know the "norms" within the specific line of industry in which the patient works.[17] Normative values for FC may be a step forward in research and practice, and narrow the gap between workload and work capacity. They may help clinicians to compare the results of a patient's FC with normative values for a patient's specific physical demand category. On the basis of this comparison, clinicians can make more accurate return-to-work recommendations and set goals for rehabilitation programs. Insurance medicine may benefit from these normative data because it may improve insurance physicians' judgments concerning workability of claimants. For clinical interpretation, it is assumed that when FC of healthy workers is equal to or exceeds their workload, the FC of healthy workers may be considered the norm to which the FC of patients can be compared. Comparing FC to normative values of healthy subjects performing in the same category of workload may indicate the following: (1) when the patient's FC is equal to or greater than the lowest valid cutoff point of the relevant norm group, the FC of the patient is sufficient to meet the workload; and (2) when the patient's FC is less than the lowest valid cutoff point of the norm group, it is unknown whether the FC of the patient is sufficient to meet the workload. Additional assessment of physical work demands related to capacity may be necessary.

The advantage of comparing FC to normative values instead of workload is that it enables clinicians to screen for a potential imbalance between workload and work capacity without performing a workplace assessment and to gain additional information concerning the FC of patients in relation to a norm group. These normative values are to our knowledge, unknown or unpublished for any FCE protocol. The aim of this study was to gain normative values for an FCE in a sample of healthy workers.

METHODS

Subjects

To collect normative values for the FCE, data of healthy subjects were obtained. Included were working subjects between 20 and 60 years of age, working in a wide range of occupations. Subjects were recruited via local press and personal networks.

Procedures

Before the FCE, subjects filled in a set of questionnaires concerning general demographics, self-reported health, and self-reported habitual physical activity. General demographics included sex, age, weight, height, education level, and work status. Self-reported health was assessed by means of the RAND-36 Health Survey, a generic health measuring scale covering 9 domains of functioning and well-being. These are vitality, mental health, social functioning, general health perception, pain, role limitations (emotional problem), role limitations (physical problem), physical functioning, and health change.[18] Self-reported habitual physical activity in sports, leisure, and work was assessed by means of the Baecke questionnaire.[19]

Risks when performing physical exercise were assessed by means of the Physical Activity Readiness Questionnaire.[20,21] The Physical Activity Readiness Questionnaire is a screening list consisting of 7 questions concerning risk factors for musculoskeletal and cardiovascular pathology (eg, do you feel pain in your chest when you do physical activity?).

Inclusion criteria were signing of an informed consent; meeting the criteria of the Physical Activity Readiness Questionnaire; a resting systolic and diastolic blood pressure of less than 159mmHg and 100mmHg, respectively[22]; age between 20 and 60 years; and subjects working at least 20 hours a week with no absenteeism from work because of musculoskeletal complaints for more than 2 weeks (5%) during 1 year before the FCE. On completion of the FCE, subjects received their personal results, a coupon of €15, and travel expenses.

Subjects performed a 2-hour, 12-item FCE covering 5 domains of physical activity. The domains were material handling, postural tolerance, coordination and repetition, hand and finger strength, and energetic capacity. After an introduction to general FCE procedures, subjects were verbally instructed on how to perform each individual test. Each test was also demonstrated by the evaluator. Subjects were allowed to begin the next test when the heart rate was below 70% of the age-related estimated maximum heart rate (220 – age). Testing order was fixed. Subjects were individually evaluated by 1 of 15 physical therapy students who had completed a 2-day FCE training by a licensed WorkWell trainer specifically for this purpose. Interrater reliability of the WorkWell FCE has previously been found to be excellent[23] and was not calculated for this study. However, students were trained until acceptable agreement between evaluators was reached. This study was approved by the Medical Ethical Committee of the University Medical Center Groningen, The Netherlands.

Functional capacity evaluation. The FCE in this project consisted of 12 tests, based largely (but not fully) on the WorkWell FCE (the former Isernhagen Work Systems FCE).[24] With respect to the WorkWell FCE, the forward bend test was adapted by loading the thoracic spine with an additional 5-kg weight, and the Bruce treadmill test was included to measure energetic capacity. Procedures, objectives, and psychometric qualities of the tests are listed below.

Material Handling

Lifting low. Objective: capacity of lifting from table to floor. Materials: plastic receptacle (40×30×26cm). A wall-mounted system with adjustable shelves and weights of 1.0, 2.0, and 4.0kg. Procedure: 5 lifts from table at 74cm to floor and vice versa in standing position within 90 seconds. Four to 5 weight increments until maximum amount of kilograms was reached. Test-retest reliability: in LBP patients (ICC=.81)[25] and in healthy subjects (ICC=.95).[26] ICF code: d4300.

Overhead lifting. Objective: capacity of overhead lifting task. Materials: plastic receptacle (40×30×26cm). A wall-mounted system with adjustable shelves and weights of 1.0, 2.0, and 4.0kg. Procedure: 5 lifts from table (74cm) to crown height and vice versa in standing position within 90 seconds.

Four to 5 weight increments until maximum amount of kilograms was reached. Test-retest reliability: in LBP patients (ICC=.87)[25] and in healthy subjects (ICC=.89).[26,27] ICF code: d4300.

Carrying. Objective: capacity of 2-handed carrying. Materials: plastic receptacle (40×30×26cm). A wall-mounted system with adjustable shelves and weights of 1.0, 2.0, and 4.0kg. Procedure: 20m carrying at waist height with receptacle within 90 seconds. Four to 5 weight increments until maximum amount of kilograms was reached. Test-retest reliability: in LBP patients (ICC=.81)[25] and in healthy subjects (ICC=.84).[26] ICF code: d4302.

Postural Tolerance

Overhead working. Objective: capacity of postural tolerance of overhead working. Materials: aluminum plate adjustable in height with 20 holes, bolts, and nuts and 2 cuff weights of 1.0kg each. Procedure: standing with hands at crown height, manipulating nuts and bolts wearing cuff weights around the wrists. The time that the position was held was measured in seconds. Test-retest reliability: healthy subjects (ICC=.90).[27] ICF code: d4158.

Forward bending stand. Objective: measure postural tolerance of forward bending. Materials: a wall-mounted system with a shelf at 74cm height. Bolts and nuts and 1 weight of 5.0kg. Procedure: standing with flexed trunk between 30° and 60°, manipulating nuts and bolts. Upper thoracic spine is loaded with a weight of 5.0kg, placed between center and shoulder blade at approximately T3. The time that position is held was measured (s). Test-retest reliability without weight: in LBP patients (ICC=.96)[25] and in healthy subjects (ICC=.93).[26] ICF code: d4158.

Coordination and Repetitive Tasks

Dynamic bending. Objective: capacity of repetitive bending and reaching. Materials: 20 marbles and 2 bowls with a 14-cm diameter positioned at floor and crown height. Procedure: standing with knees flexed between 0° and 30°, move marbles vertically from floor to crown height as fast as possible. Time needed to remove 20 marbles is scored (s). Test-retest reliability: in LBP patients (ICC=.72)[25] and in healthy subjects (ICC=.45).[26] ICF code: d4452.

Repetitive side reaching. Objective: capacity of fast repetitive side movements of the upper extremity. Materials: 30 marbles and 2 bowls with a 14-cm diameter positioned at table height (74cm). Procedure: sitting with bowls on wingspan distance, move marbles horizontally at table height from right to left with right arm as fast as possible and vice versa. Time needed to move 30 marbles is scored (s). Test-retest reliability: in LBP patients (ICC=.45–.64)[25] and in healthy subjects (ICC=.54–.72).[26] ICF code: d4452.

Fingertip dexterity. Objective: capacity of fingertip dexterity. Materials: Purdue Pegboard (model no. 32020).[a] Procedure: sitting subject in front of the pegboard, placing pins with left and right hand as fast as possible in a 30-second trial. Average number of pins placed in 30 second over 3 trials in both hands was scored. Test-retest reliability: 3-trial score in healthy subjects (ICC=.73–.91).[27,28] ICF code: d4458.

Hand and forearm dexterity. Objective: gross movement coordination of fingers, hands, and arms. Materials: a Complete Minnesota Dexterity Test.[a] Procedure: sitting subject displacing 59 blocks in a predetermined way as fast as possible. Total displacing time needed to perform 4 trials with both hands was scored. Test-retest reliability: 4-trial score in healthy subjects (ICC=.77–.98).[27,29,30] ICF code: d4458.

Hand and Finger Strength

Handgrip strength. Objective: isometric grip strength. Materials: a hand dynamometer (Jamar PC 5030).[b] Procedure: in a seated position, the subjects held their shoulder adducted and neutrally rotated, elbow flexed at approximately 90°, and the forearm and wrist in neutral position.[31-33] Grip strength of the right and left hand was measured in a 3-trial procedure. Only the second handgrip position will be reported in this article. Average amount of kilogram-force was scored. Test-retest reliability: in healthy subjects (ICC>.93).[31] ICF code: d4400/s73022.

Finger strength. Objective: isometric tip, key, and palmar pinch strength. Materials: a pinch-grip dynamometer (Preston Pinch Gauge).[b] Procedure: in a seated position, the subjects held their shoulder adducted and neutrally rotated, elbow flexed at approximately 90°, the forearm and wrist in neutral position.[31,32] For the tip pinch, subjects pinched for 3 seconds with index finger above thumb. Facilitation of middle finger was not permitted. Palmar strength was measured with both index and middle finger on top and thumb below the dynamometer. Key strength was measured using pinch strength of thumb on top. Strength of right and left fingers was measured in a 3-trial procedure. Average kilogram-force was scored. Test-retest reliability: in healthy subjects (ICC>.76).[27] ICF code: d4400/s73022.

Energetic Capacity

Objective: To predict the maximum oxygen consumption (presented in METs) by submaximal Bruce treadmill test.[34] Materials: treadmill with a slope capacity of 22% and a heart rate monitor. Procedure: the treadmill is set up with the stage 1 speed (2.7km/h) and grade of slope (10%), and the subject commences the tests. Every 3 minutes, slope and speed are adjusted following the Bruce protocol. Test is terminated when subject's 85% of age-related max is reached. Prediction of maximum oxygen consumption was done according to the following formula:

$$\text{METs} = [16.62 + 2.74\,(1.17 \text{ minutes of exercise}) - 2.584\,(\text{weighting factor for sex}) - 0.043\,(\text{years of age}) - 0.0281\,(\text{kg body weight})]/3.5$$

where weighting factor for sex is 1 for men and 2 for women.[35] Test-retest reliability: in healthy subjects (r=.99).[35] ICF code: b4551.

Test Termination Criteria

Tests were terminated in one of the following situations (whichever came first): (1) cardiac endpoint, (2) biomechanical endpoints, or (3) subject endpoints. The cardiac endpoint was reached when the heart rate was greater than 85% of the age-related estimated maximum (220 – age). Heart rate was measured with a heart rate monitor. Biomechanical endpoints were reached when loss of solid standing basis during lifting tasks or loss of control of the load was observed.[24] Biomechanical endpoints were determined by the evaluators. Subject endpoints were reached when subjects stopped the test. Subjects were allowed and instructed to stop at any point that they wished.

Analyses

Subjects were classified into 4 categories of workload, based on their current occupations, following the physical demands used in the DOT (sedentary, light, medium, heavy/very heavy). The physical demands were classified according to the criteria

Table 1: Physical Demand Characteristics of Work

Physical Demand Level	Occasional* 0%–33% of the Workday	Frequent* 34%–66% of the Workday	Constant* 67%–100% of the Workday
DOT 1: Sedentary	4.5kg	Negligible	Negligible
DOT 2: Light	9.1kg	4.5kg	Negligible
DOT 3: Medium	22.7kg	9.1kg	4.5kg
DOT 4: Heavy/very heavy	45.4kg	22.7kg	9.1kg

NOTE. Examples of DOT 1: medical secretary, manager branch (any industry), clinical psychologist; DOT 2: teacher elementary school, receptionist, computer operator; DOT 3: nurse (general duty), maintenance engineer (any industry), carpenter, car mechanic; DOT 4: baker, bricklayer, farm worker general.
*Amount of force exerted to lift, carry, push, pull, or otherwise move objects, including the human body.

presented in table 1. Examples of occupations classified in the DOT are provided in table 1. The workload categories heavy and very heavy were merged because the number of subjects working in these demand categories was expected to be small. In order to provide normative values, means, ranges, SDs, and percentiles were calculated. In addition, linear regression analyses (method enter) were performed with test results as outcome variables and gender (female=0, male=1), age (y), height (cm), weight (kg), and DOT categories as predictor variables. DOT categories 2, 3, and 4 were entered as dummy variables in the regression equation.

RESULTS

Subjects

A total of 701 subjects were included in this study (448 men, 253 women). These subjects represented more than 180 different occupations. No women were identified who were working in DOT category 4 (heavy/very heavy). Characteristics of the subjects are presented in table 2.

Material Handling

The domain material handling consisted of 3 different tests: lifting low, lifting high, and carrying. The results of these tests are presented in table 3.

Postural Tolerance

The domain postural tolerance consisted of 2 tests: the Overhead Work Test and the Forward Bending Test. Results are presented in table 4.

Coordination and Repetition

The domain coordination and repetition consisted of 4 tests: the Purdue Pegboard Task, Repetitive Side Reach Test, Dynamic Bending, and the Complete Minnesota Dexterity Test. Results are presented in table 5.

Hand Strength

The domain hand strength consisted of 2 tests: isometric grip and finger strength. Results are presented in table 6.

Table 2: Characteristics of Participants, Their Work, and RAND-36 Scores

Characteristics	DOT 1	DOT 2	DOT 3	DOT 4	Total Group
n	120	229	304	48	701
Age (y)	43.4±9.4	44.1±9.8	38.8±10.3	39.7±10.9	41.4±10.3
Male n (%)	59 (49)	132 (57)	210 (69)	48 (100)	448 (64)
Body height (cm)	176.6±9.8	177.7±8.8	176.7±8.4	184.1±7.8	177.5±8.9
Body weight (kg)	75.6±13.8	76.2±12.7	78.2±14.5	86.5±16.0	77.7±14.1
Body mass index	24.1±3.4	24.1±3.1	24.9±4.0	25.7±5.0	24.6±3.7
Hand dominance (L/R/A)	18/98/4	24/197/8	31/257/16	10/33/5	83/585/33
Hours per week working	36.2±8.2	35.5±8.0	35.5±8.6	41.2±11.3	36.0±8.6
Years at present work	8.1±8.1	11.9±9.7	10.8±9.6	14.4±11.8	10.9±9.7
Baecke score					
1. Work (1–6)	2.2±0.4	2.6±0.6	3.3±0.5	3.8±0.5	2.9±0.7
2. Sport (1–6)	3.2±1.1	2.9±1.1	2.7±1.2	2.6±1.2	2.8±1.2
3. Leisure time (1–6)	3.2±0.6	3.2±0.6	3.0±0.7	2.9±0.6	3.1±0.6
RAND-36					
1. Vitality (0–100)	66.3±12.8	66.8±13.0	66.7±11.7	68.2±12.9	66.8±12.4
2. Mental health (0–100)	71.0±9.5	71.4±10.2	71.2±9.9	74.8±9.7	71.5±10.0
3. Social functioning (0–100)	92.0±12.6	89.8±15.4	90.3±13.9	92.5±10.8	86.2±15.0
4. General health perception (0–100)	76.4±15.3	77.0±15.1	73.8±15.5	74.1±15.1	75.3±15.3
5. Pain (0–100)	93.3±12.3	91.6±11.2	90.1±11.8	92.8±9.1	91.3±11.6
6. Role limitation (emotional) (0–100)	91.9±24.9	91.7±23.9	95.0±19.1	99.3±4.8	93.7±21.4
7. Role limitation (physical) (0–100)	93.8±18.0	95.7±16.6	92.3±19.5	94.8±16.3	93.8±18.1
8. Physical functioning (0–100)	96.0±7.2	96.9±6.2	94.1±11.4	97.2±6.2	95.6±9.1
9. Health change (0–100)	52.7±16.8	52.0±15.0	54.7±16.1	54.3±18.3	53.4±16.0
Education*					
1. Low	0	4	25	3	32
2. Intermediate	60	81	178	40	359
3. High	56	139	83	5	283
4. Unknown	4	5	18	0	27

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviations: A, ambidextrous; L, left handed; R, right handed.
*Low (primary school unfinished and finished); intermediate (secondary school and junior college); high (bachelor's degree and university).

Table 3: Normative Values for Material Handling (in kg) for the Different DOT Categories

	Lifting Low (kg)				Lifting High (kg)				Carrying (kg)			
	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4
Mean ± SD	36±15	38±15	41±14	53±14	16±6	17±6	18±6	24±5	38±14	40±14	43±13	53±11
Range	8–72	12–80	10–78	20–76	4–30	4–40	5–34	12–36	13–68	8–77	10–76	20–74
Percentiles												
1	8	14	12	20	4	8	7	12	13	14	16	20
5	16	18	19	24	7	8	8	12	16	20	20	29
10	18	20	24	34	8	10	10	15	21	24	24	40
20	24	24	28	40	10	10	12	20	25	28	32	45
30	25	28	34	45	12	12	15	24	28	31	35	48
40	28	32	38	49	12	14	16	24	32	34	40	50
50	33	36	40	54	15	16	20	24	36	39	45	53
60	37	40	45	56	17	18	20	24	40	42	48	56
70	44	46	50	60	20	20	21	26	47	50	50	59
80	50	52	55	66	20	22	25	28	52	54	55	64
90	60	60	60	72	24	24	25	32	56	60	60	70
95	64	67	65	75	27	28	30	32	60	64	64	72
99	71	76	73	76	30	35	32	36	68	75	70	74

NOTE. DOT categories: 1 (sedentary); 2 (light); 3 (medium); 4 (heavy/very heavy work).

Energetic Capacity

The energetic capacity domain consisted of the submaximal Bruce Treadmill Test. Results are presented in table 7.

Prediction of Outcome

In table 8, results of the regression analyses are presented. To predict test outcome related to the personal variables sex, age, height, body weight, and DOT category, subjects' personal characteristics can be inserted in the regression equation. Two examples of different persons working in different occupations are provided in table 8. Depending on the test, outcome can be predicted from 5% to 59% from the variables sex, age, height, body weight, and workload (see table 8). The variance in strength and material handling tests can be largely explained by sex. The Postural Tolerance tests can only minimally be predicted.

DISCUSSION

The establishment of normative values for an FCE may improve clinicians' recommendations for return to work, because comparing patients' FC to normative values instead of to data gathered from a workplace assessment enables clinicians to screen for potential imbalances between workload and work capacity without having to perform a workplace assessment, while at the same time gaining additional information concerning the FC of patients in relation to a norm group. The normative values gathered in this study were performed with subjects who have reported good health and participation in work in the year before the FCE. This means that capacity as measured in the FCE is sufficient to meet the workload in all subjects. For clinical use, when the patient's FC is equal to or exceeds the lowest valid case in the norm group, FC is sufficient to meet the workload. These norms, therefore, provide information about a

Table 4: Normative Values for Postural Work for the Different DOT Categories

	Overhead Work Test (s)				Forward Bend Test (s)			
	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4
Mean ± SD	260±135	246±105	264±122	280±117	420±343	342±282	363±312	424±314
Range	77–1139	68–826	75–818	97–690	49–1925	10–217	65–306	140–1899
Percentiles								
1	97	72	77	97	55	81	85	140
5	101	103	100	128	99	110	122	164
10	125	124	123	171	128	142	146	189
20	171	162	166	211	180	175	170	209
30	191	186	195	221	215	206	209	262
40	219	205	220	232	253	240	240	300
50	249	234	247	242	326	263	281	334
60	278	257	272	250	365	307	315	374
70	301	280	302	281	458	355	368	421
80	325	324	336	366	570	432	450	512
90	361	384	424	420	912	609	678	877
95	422	430	516	587	1127	714	934	1106
99	1080	571	657	690	1915	1939	1682	1899

NOTE. DOT categories: 1 (sedentary); 2 (light); 3 (medium); 4 (heavy/very heavy work).

Table 5: Normative Values for Repetitive and Coordinative Tests for the Different DOT Categories

	Purdue Pegboard Task (no. of pins)*				Side Reach Test (s)				Dynamic Bending (s)				Complete Minnesota Dexterity Test (s)†			
	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4
Mean ± SD																
Right	16.6±1.9	16.1±2.0	15.9±1.9	15.3±1.5	72±12	73±12	76±11	76±10	45±6	45±6	47±6	45±5	176±21	182±23	184±24	188±22
Left	15.9±1.6	15.4±1.7	15.2±1.6	15.2±1.6	73±11	74±11	76±11	77±11					183±20	191±24	194±24	193±22
Range																
Right	12.3–23.3	11.0–21.3	9.7–20.3	11.7–18.0	49–118	53–124	51–116	59–103	35–65	33–72	32–76	36–58	125–250	134–257	138–306	153–250
Left	11.7–20.3	10.7–21.3	9.7–20.3	11.7–18.3	49–133	53–116	53–110	57–110					139–234	126–271	138–303	153–275
Percentiles																
1																
Right	12.4	11.4	10.4	11.7	116	118	114	103	64	67	71	58	248	244	272	250
Left	11.8	11.0	11.0	11.7	125	108	105	110					234	266	275	275
5																
Right	13.6	12.7	12.4	12.4	94	94	97	93	55	56	60	55	217	228	226	234
Left	13.7	12.2	12.3	11.8	93	95	98	98					221	236	235	232
10																
Right	14.0	13.3	13.7	12.9	87	87	91	90	52	52	55	51	204	214	211	219
Left	14.0	13.0	13.0	12.7	86	89	91	92					210	221	220	218
20																
Right	15.3	14.3	14.7	13.7	81	82	84	87	49	49	51	49	191	199	202	205
Left	14.6	14.0	13.7	14.1	80	82	85	85					197	208	211	210
30																
Right	15.7	15.3	15.0	14.7	77	78	80	82	46	47	49	47	183	190	192	192
Left	15.0	14.7	14.3	14.3	78	78	81	80					193	200	204	201
40																
Right	16.0	15.7	15.7	15.0	75	74	78	77	45	45	47	45	179	184	186	188
Left	15.3	15.0	14.7	14.8	74	76	78	79					186	194	196	195
50																
Right	16.7	16.0	16.0	15.3	71	71	75	75	44	44	46	45	175	179	181	186
Left	15.7	15.7	15.3	15.3	70	73	75	77					180	189	191	191
60																
Right	17.0	16.7	16.3	16.0	68	69	73	71	43	43	45	43	169	174	176	181
Left	16.1	16.0	15.7	15.9	69	70	73	72					176	182	187	187
70																
Right	17.7	17.3	16.8	16.3	66	67	70	69	41	41	42	43	165	167	170	178
Left	16.7	16.4	16.0	16.0	67	67	70	70					171	177	182	183
80																
Right	18.1	18.0	17.7	16.3	62	63	67	67	40	40	41	41	158	162	166	168
Left	17.1	17.0	16.3	16.3	64	65	67	66					165	172	175	172
90																
Right	18.7	18.3	18.2	17.1	60	60	63	65	38	38	39	39	152	156	157	160
Left	18.0	17.3	17.0	17.3	59	61	63	64					159	165	167	167
95																
Right	19.4	19.3	18.7	17.6	54	57	60	64	37	37	37	38	146	150	154	155
Left	18.7	17.7	18.0	17.7	56	58	60	62					150	159	161	165
99																
Right	22.9	20.7	19.7	18.0	49	53	52	59	35	34	34	36	126	141	140	153
Left	20.3	20.2	19.0	18.3	50	54	55	57					139	141	150	153

NOTE. DOT categories: 1 (sedentary); 2 (light); 3 (medium); 4 (heavy/very heavy work).
*Mean no. of pins placed in 3 trials.
†Total time of 4 trials.

Table 6: Normative Values for Hand and Finger Strength for the Different DOT Categories

	Handgrip Strength (kg)*				Tip Pinch Strength (kg)*				Palmar Pinch Strength (kg)*				Key Pinch Strength (kg)*			
	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4	DOT 1	DOT 2	DOT 3	DOT 4
Mean ± SD																
Right	40.8±12.2	42.3±11.7	43.7±12.0	54.1±11.2	5.2±1.7	5.6±1.7	5.3±1.6	6.4±1.9	7.7±2.0	8.0±2.0	7.5±2.0	8.9±2.0	8.8±2.1	9.2±2.1	8.9±2.2	11.0±2.1
Left	38.4±12.5	39.5±12.0	41.3±11.7	53.3±11.6	5.0±1.7	5.4±1.7	5.1±1.7	6.7±1.8	7.2±2.0	7.6±2.0	7.1±2.0	8.9±2.1	8.5±2.2	8.9±2.2	8.7±2.1	10.6±2.0
Range																
Right	19.0–73.3	19.7–69.3	20.6–72	29.3–80.3	1.8–9.0	1.3–11.7	1.5–10.5	0.5–12.7	3.7–14.3	2.7–13.0	2.3–13.3	2.5–12.5	4.7–16.5	4.5–15.0	3.2–15.0	7.0–15.8
Left	15.0–71.0	19.0–68.0	18.7–71.3	26.0–91.3	2.1–9.7	1.5–11.0	1.5–12.7	0.8–11.8	2.8–12.5	3.0–13.0	2.0–13.0	2.7–13	4.3–16.7	3.5–14.3	3.8–15.5	7.0–16.3
Percentiles																
1																
Right	19.2	21.3	21.3	29.3	1.9	1.9	2.0	0.5	3.7	3.5	2.5	2.5	4.7	4.6	4.7	7.0
Left	15.4	19.8	18.7	26.0	2.2	1.7	1.7	0.8	2.9	3.7	3.0	2.7	4.4	4.1	4.3	7.0
5																
Right	23.3	25.5	24.7	32.8	2.7	3.0	2.7	4.5	4.3	5.0	4.2	5.4	5.6	6.0	5.5	7.2
Left	21.3	22.3	22.0	32.2	2.5	2.9	2.3	3.9	3.8	4.6	3.8	5.5	5.2	5.7	5.0	7.2
10																
Right	26.0	27.7	27.3	40.5	3.2	3.5	3.2	4.8	5.2	5.5	5.1	6.8	6.3	6.7	6.2	8.3
Left	24.7	24.3	25.7	40.3	2.9	3.2	3.0	4.6	4.7	5.2	4.5	6.2	5.5	6.2	5.8	8.0
20																
Right	31.0	30.0	32.5	44.6	3.7	4.2	3.8	5.0	6.0	6.2	5.8	7.2	6.8	7.2	7.0	9.1
Left	27.9	28.0	29.9	43.3	3.6	4.0	3.6	5.3	5.5	5.8	5.5	6.9	6.8	7.0	6.8	9.2
30																
Right	32.7	33.7	35.7	48.7	4.2	4.7	4.3	5.3	6.3	6.7	6.5	7.8	7.7	7.7	7.7	9.8
Left	29.9	31.0	33.3	47.9	4.0	4.3	4.2	6.0	6.1	6.5	6.0	7.3	7.4	7.3	7.5	9.7
40																
Right	34.7	37.7	40.4	51.2	4.5	5.0	4.8	5.9	6.8	7.2	7.0	8.3	8.0	8.3	8.3	10.7
Left	32.7	33.7	37.7	49.1	4.3	4.8	4.5	6.4	6.7	7.0	6.7	9.1	7.8	8.0	8.2	10.2
50																
Right	37.8	41.7	43.7	54.0	4.8	5.5	5.2	6.3	7.5	7.8	7.5	8.5	8.5	9.2	9.0	10.8
Left	34.3	38.0	42.0	52.0	5.0	5.2	5.0	6.8	7.2	7.5	7.2	9.5	8.3	8.7	8.7	10.5
60																
Right	43.7	45.7	47.3	56.9	5.7	6.0	5.7	6.7	8.0	8.5	7.8	9.5	9.0	9.7	9.6	11.3
Left	39.5	42.0	46.0	56.0	5.3	5.7	5.3	7.1	7.7	7.8	7.7	9.7	8.8	9.3	9.3	10.9
70																
Right	48.1	50.0	50.8	59.7	6.2	6.5	6.0	7.0	8.7	9.0	8.3	10.4	10.0	10.3	10.3	12.4
Left	46.8	46.7	48.7	60.2	5.8	6.3	5.8	7.5	8.0	8.5	8.0	10.2	9.6	10.2	9.8	11.0
80																
Right	51.7	54.3	55.0	62.3	6.8	7.0	6.5	7.6	9.3	9.7	9.0	10.8	10.8	11.0	10.8	12.8
Left	50.3	52.3	52.1	61.0	6.5	6.8	6.3	8.1	9.2	9.3	8.7	10.7	10.3	11.0	10.3	11.8
90																
Right	60.0	58.3	59.7	68.4	7.6	7.7	7.3	8.6	10.4	11.0	10.1	11.5	11.4	12.0	11.6	13.9
Left	54.8	56.7	57.0	67.6	7.2	7.7	7.2	8.4	10.1	10.5	9.7	11.4	11.5	12.	11.5	13.9
95																
Right	62.0	62.0	63.4	76.7	8.2	8.1	8.0	9.9	11.1	11.3	11.0	12.3	12.4	12.7	12.7	14.9
Left	61.1	59.8	59.3	70.2	8.4	8.3	8.0	9.8	10.9	10.9	10.8	11.6	12.4	12.4	12.5	15.3
99																
Right	72.6	67.4	69.1	80.3	9.0	11.1	10.3	12.7	14.0	12.6	12.5	12.5	16.2	14.6	14.5	15.8
Left	70.6	66.1	66.3	91.3	9.6	10.7	10.0	11.8	12.3	12.5	12.2	13.0	16.3	13.7	13.3	16.3

NOTE. DOT categories: 1 (sedentary); 2 (light); 3 (medium); 4 (heavy/very heavy work).
*Mean kilograms out of 3 trials.

Table 7: Normative Values for Energetic Capacity for the Different DOT Categories

	Estimated Energetic Capacity (METS)*			
	DOT 1	DOT 2	DOT 3	DOT 4
Mean ± SD	9.5±2.3	9.7±2.3	9.7±2.3	10.6±2.6
Range	3.7–15.0	3.7–17.5	2.8–17.2	3.7–14.3
Percentiles				
1	4.1	4.7	4.0	3.7
5	5.9	6.2	6.3	5.9
10	6.9	7.5	6.9	7.9
20	8.0	8.3	8.3	8.9
30	8.3	8.6	8.7	9.4
40	8.6	9.1	9.2	10.2
50	9.2	9.5	9.6	11.5
60	10.0	10.1	10.0	11.6
70	11.0	10.8	10.8	11.8
80	11.5	11.5	11.5	12.1
90	12.1	11.9	12.1	13.0
95	12.8	12.8	12.9	14.1
99	14.9	15.5	14.8	14.3

NOTE. DOT categories 1–4: 1 (sedentary); 2 (light); 3 (medium); 4 (heavy/very heavy work).
*1 MET is 3.5mL O_2/min/kg.

minimal required capacity. In fact, capacity of the lowest performing subject in the FCE should be sufficient for successful work in the corresponding DOT category. If a subject's capacity is below that of the lowest performing subject, it is unclear whether this capacity may still be sufficient for the particular workload. Additional assessment of physical work demands related to capacity may in those cases be necessary. The WorkWell FCE protocol, on which the selection of tests in this research was partly based, extrapolates its test results to a normal working day. This extrapolation is based on the assumption that test results of lifting and carrying, in which an observed effort level of heavy was identified by the evaluator, correspond to the physical demand that is required occasionally.[23] If the subjects' FCE results, classified with an observed effort level of heavy or very heavy, were compared with the physical demands of table 1, then all subjects who were classified in the DOT categories of sedentary and light met the lifting and carrying work demands. However, capacity of 6% and 28% of the subjects working in the medium and heavy categories, respectively, the maximum work demand to meet was not met.[36] Based on the work demands of the DOT, a valid comparison of the lifting and carrying scores with the DOT implies that comparing to the 1st percentile is valid for the sedentary and light occupations, the 10th percentile is valid for medium occupations, and the 30th percentile is valid for the heavy and very heavy occupations. Occupations classified as having equally heavy workloads in the DOT vary considerably by industry (eg, same DOT category, different profession) or by person. Since the appearance of the fourth edition of the DOT in 1991, mechanization and automation in many occupations in Western society have continued, which usually has made work less demanding physically, suggesting that occupations categorized as heavy may, in fact, no longer require the demands to fit the category heavy. Because this might pose a challenge to the validity of the DOT, updated information on work demands in new occupations will provide better knowledge of physical workloads. The reason the DOT was used in this research is that, to our knowledge, no other widely acknowledged standard seems to be available.

Study Limitations

One of the limitations of this research is that FCE focuses largely on the physical part of capacity. When capacity is evaluated in a biopsychosocial context, as described in the ICF and agreed on among FCE experts,[8] capacity refers to the highest probable level of functioning that a person may reach in a domain at a given moment in a standardized environment.[37] The context in which work takes place, however, significantly differs from the standardized environment in which the FCE takes place. Translation of capacity testing into performance in daily life continues to be challenging because other barriers may hinder patients to successfully return to their jobs. Seen from that perspective, measuring the "bio" aspect solely will be insufficient for most applications in rehabilitation, occupational, and insurance medicine. FC may, however, function as one of the prerequisites for returning to work.[38] Furthermore, the capacity of some of the tests is largely dependent on personal characteristics such as age and sex (see examples in table 8). Clinicians who are interested in a patient's capacity in comparison with healthy subjects with corresponding sex, age, weight, and height can use the regression equations as provided in table 8. For the strength tests (lifting low, lifting high, carrying, hand strength), 34% to 59% of variance can be explained by personal factors. In these tests, sex is the main predictor that corresponds with results from previous studies.[32] Remarkably, age was not found to be significantly predictive for handgrip and pinch strength, whereas in a different study,[39] handgrip strength was found to decline progressively after the age of 60. Significant declines in handgrip strength were small from the ages of 25 to 55.[39] Further research with corrections for multiple personal factors is needed in order to draw some grounded conclusions. The static endurance tests were found to have very low explained variance (overhead work and forward bending; 8% and 5%, respectively). This means that static workload can be performed equally between men and women and that it is independent of age, body height, and body length. It is recommended that clinicians take into account the varying percentage of explained variance when using these regression equations, as provided in table 8, in practice. The reason, however, that the researchers have chosen to present all normative values not specified by sex and age is that capacity should be sufficient to overcome the relevant workload regardless of age or sex.

Another point that should be addressed was the small number of subjects performing in DOT 4 (n=48). The power in this group would have been higher if inclusions in all DOT categories were divided equally. This, however, appeared to be impossible. Clinicians should keep this in mind when considering and interpreting these data as true normative data. Remarkable in this study sample is the absence of women working in DOT 4. There may be several explanations for this. One explanation is that the capacity of most women may be insufficient to work in DOT 4. When we compare the capacity of women working in other DOT categories with the work demands of DOT 4, it appears that the capacity of 98% of all women is insufficient to perform in DOT 4. Another explanation may be of a cultural nature, which is that women still are, or consider themselves to be excluded from male jobs such as construction occupations.

In clinical practice, patients' results can be compared with these normative values. Interpretation, however, may still be partly unclear. Should practitioners and therapists compare patients' results with the mean, 50th percentile, 5th percentile, or 1st percentile values? Authors have no conclusive answers to this question. Theoretically, comparisons with the 1st per-

Table 8: Prediction Models for Test Outcome on the Basis of Sex, Age, Height, Body Weight, and DOT Category

Test	Constant	Sex	Age (y)	Body Height (cm)	Body Weight (kg)	DOT 2	DOT 3	DOT 4	r^2
Lifting low	−29.2*	15.0*	−0.20*	0.31*	0.16*	0.4	1.2	4.0*	.53
Lifting high	0.6	7.2*	−0.07*	0.05	0.07*	0.3	0.9	3.3	.53
Carrying	−19.1	14.0*	−0.20*	0.30*	0.08*	1.2	1.2	4.4*	.49
Overhead work	203.5	65.8*	0.01	1.10	−2.23*	−20.4	−3.7	−9.7	.08
Forward bend	361.9	−23.8	−0.76	2.73	−5.01*	−74.9*	−42.3	45.2	.05
Dynamic bending	32.2*	1.3	0.12*	0.01	0.06*	−0.1	2.2*	−0.7	.11
Purdue Pegboard Task									
Right	23.9*	−0.9*	−0.07*	−0.01	−0.02*	−0.3	−0.7*	−0.8*	.31
Left	20.8*	−0.5*	−0.05*	−0.01	−0.02*	−0.4*	−0.7*	−0.3	.19
Side reach test									
Right	55.4*	4.4*	0.30*	−0.04	0.12*	0.2	4.2*	0.9	.18
Left	64.4*	4.6*	0.30*	−0.08	0.08*	0.8	3.9*	2.1	.16
CMDT									
Right	151.6*	5.9*	0.81*	−0.20	0.28*	5.5*	10.3*	10.2*	.21
Left	183.6*	3.9	0.73*	−0.30*	0.25*	8.3*	13.6*	11.0*	.17
Handgrip strength									
Right	−8.3	13.8*	−0.02	0.19*	0.13*	0.1	0.4	4.0*	.57
Left	−15.8	13.6*	0.02	0.21*	0.14*	−0.3	0.3	5.7*	.59
Pinch strength									
Right	0.1	1.3*	0.00	0.01	0.03*	0.3	−0.3	0.2	.34
Left	−0.9	1.3*	0.01	0.02*	0.03*	0.2	−0.2	0.7*	.36
Palmar strength									
Right	−1.8	1.7*	0.00	0.04*	0.02*	0.1	−0.5*	−0.1	.38
Left	−2.0	1.7*	0.00	0.04*	0.02*	0.2	−0.5*	0.4	.38
Key pinch strength									
Right	−3.0	1.8*	0.01	0.05*	0.04*	0.1	−0.3	0.6	.49
Left	−3.3*	1.9*	0.01	0.05*	0.03*	0.1	−0.3	0.5	.48
Energetic capacity	6.6*	1.9*	−0.04*	0.04*	−0.05*	0.06	−0.28	0.17	.28

NOTE. In the table, regression coefficients are presented for the predictor variables. Constant equals the mean value of women in the DOT 1 category with a hypothetical age of 0y, body height of 0cm, and body weight of 0kg. The DOT categories DOT 2, DOT 3, and DOT 4 reflect the mean difference in test outcomes relative to the DOT 1 category sex: 0 (women); 1 (men).
Abbreviation: CMDT, Complete Minnesota Dexterity Test.
*Significance of the coefficients at $P<.05$.
Examples:
1. Female manager secretary (DOT 1); 33 years of age; 165cm, 60kg. Prediction for Lifting Low: $-29.2 + (15 \times 0) - (0.20 \times 33) + (0.31 \times 165) + (0.16 \times 60) = 25$kg.
2. Male bricklayer (DOT 4); 25 years of age; 195cm, 100kg. Prediction for Lifting Low: $-29.2 + (15 \times 1) - (0.20 \times 25) + (0.31 \times 195) + (0.16 \times 100) + 4.0 = 62$kg.

centile values may be suitable. With respect to extreme values, and perhaps submaximal efforts made by subjects in our groups for whatever reasons, the presence of some additional capacity may be worthwhile; comparisons with the 5th or 10th percentile values may thus be recommended. Further research should focus on the lowest valid cutoff point of these normative values. Another clinically important question concerns subjects who perform below the 1st percentile. The results of this research are inconclusive, but a lower score than the 1st percentile may possibly still be sufficient to perform work. The reason for this low performance should be identified within a biopsychosocial context. Additional assessment of physical demands by means of a workplace assessment may be recommended in these cases. Further research about the validity and utility of the normative values from this study should focus on the concurrent validity of the normative values and results adapted from workplace assessments. If concurrent validity is sufficient, patients' results of capacity can be compared with these normative values in order to make work performance recommendations.

To our knowledge, the results of the present study are the first normative data of FC of healthy working subjects. A total of 701 subjects were evaluated, which leads to stability of the data. Therefore, the results should provide tools for clinicians to improve their judgments and recommendations for the physical part of work ability. This research contributes to closing the gap between workload and work capacity.

CONCLUSIONS

Overall, it can be concluded that the normative values derived from this research contribute to a better interpretation of the functional outcome of an FCE. Because of the limitations addressed in the Discussion section, we suggest that these normative values not be used as "rules" but rather as guides to support clinical decision-making.

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Suppliers

a. Lafayette Instrument Co, 3700 Sagamore Pkwy N, Lafayette, IN 47904.
b. Preston Corp, 65 Old US Highway 22, Clifton, NJ 08809.